Exploring Multi-Photon Entanglement

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Abstract:

We study the generation and possible applications in cryptography and metrology of multi-photon entangled states as produced by stimulated parametric down-conversion. The states have a rich entanglement structure. In particular, high-dimension polarization and particle-number entanglement between photons in two spatial output modes can be obtained. From this quantum state one can extract maximally-entangled multi-photon states via photon-counting. We show experimental results for the concentration of a rotationally symmetric four-photon entangled state obtained by stimulated emission of the familiar anti-symmetric two-particle Bell state [1]. This four-photon state is analogue to a two-particle spin-1 singlet and we have demonstrated the first spin-1 Bell inequality violation using this state [2]. The higher order multi-photon contributions correspond to spin-n/2 singlet states. The entanglement structure makes the produced state a natural candidate for quantum key distribution and applications in quantum metrology. We propose a high bit-rate quantum cryptography scheme [3] and point out the crucial role that multi-photon counters will play in the realization of the scheme. Multi-photon detectors will also play a key role in the realization of quantum metrology schemes. We will discuss the required properties of the multi-photon detectors and propose a scheme to produce nano devices that can meet those requirements. We also report on another project in progress that aims at measuring the force exerted on a tiny mirror by a single photon. This research should lead to state-of-the-art atomic force microscopes and position sensors. I will conclude with some comments on remote sensing.

[1] Lamas-Linares, A., Howell, J.C. & Bouwmeester, D. *Stimulated emission of polarization-entangled photons*, Nature (London), **412**, 887 (2001).

[2] Howell, J.C., Lamas-Linares, A. & Bouwmeester, D. *Experimental violation of a spin-1 Bell inequality using maximally-entangled four-photon states*, Phys. Rev. Lett**. 88**, 030401 (2002).

[3] Durkin, G., Simon, C. & Bouwmeester, D. *Multi-photon entanglement concentration and quantum cryptography*, Phys. Rev. Lett. **88,** 187902, (2002).